FRIEDENTHAL'S EXPERIMENTAL PROOF OF BLOOD-RELATIONSHIP.[1]

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In recent years important evidence in favor of Darwin's theory of the descent of man has increased. Eugen Dubois found in *Pithecanthropus erectus* the much-sought-for missing link between man and living anthropoid apes. Selenka has shown that, of the catarrhine apes, the living anthropoid apes resemble man in having a placenta discoidalis capsularis, while all other catarrhines have a placenta bidiscoidalis. Ernst Haeckel has accumulated evidence showing that man has descended from a line of extinct catarrhines whose immediate ancestors belonged to the group of tailless anthropoid apes, and whose more remote ancestors belonged to the Cynopithecini. The evidence afforded by comparative paleontology, comparative embryology, and comparative anatomy agrees in supporting Darwin's hypothesis.

To all this evidence is now added evidence depending upon the similarity in chemical composition of the blood of closely related animals. Comparative chemical analyses of blood are attended with great difficulties because of variations in the blood depending upon the varying conditions of nutrition in the animal. Landois, in his researches on the effects of animal blood transfusions upon human diseases, attributed his failures, so far as the beneficial effects of the blood transfusion upon the disease were concerned, to the dissolving of the red blood corpuscles of the injected blood by the blood of the recipient. Experiments upon lower animals, in the way of injecting blood from some animal of a remote species, led to the same results as the experiments upon man. The animals

[1] An extended abstract of a paper by Hans Friedenthal: Ueber einen experimentellen Nachweis von Blutverwandschaft, *Archiv für Anatomie und Physiologie*, physiologische Abtheilung, Hefte 5 und 6, 1900.

exhibited pathological conditions with development of fever, or very often died soon after the transfusion. The hemoglobin of the foreign erythrocytes appeared in the bladder immediately after the transfusion, and often more hemoglobin was given off than was contained in the injected blood. The dissolving of red blood corpuscles by the serum of foreign blood was first observed under the microscope by Creite.

Landois found, in some cases, that the dissolving of the injected blood elements did not occur. In transfusions between the horse and ass, wolf and dog, rabbit and hare, no hemoglobin appeared in the urine; the animal, even after the injection of a large amount of blood, showed no pathological symptoms, but behaved precisely as after an injection of blood from one of its own kind. Landois concluded that *only animals of very closely related species can exchange blood with impunity*. The question then arises, How closely related must animals be in order that their blood may be "physiologically identical"?

The method of blood transfusions is not adapted to extensive comparative researches. But the "globulicidal" action of a blood serum can be observed to advantage in a test-tube. To 10 c.cm. of the serum of some mammal let there be added three drops of foreign blood from which the fibrin has been removed, and let the mixture be kept at 38° for fifteen minutes. The mixture is at first opaque, because of the added erythrocytes, but at the end of the fifteen minutes the fluid regains its transparency and acquires a bright red, owing to the dissolving of the coloring matter from the added red corpuscles. Buchner found that if the serum is heated to 55° its power of dissolving foreign corpuscles is quite lost. Buchner also found that serum would dissolve the white corpuscles of foreign blood.

The loss of the dissolving power of serum as a result of raising the temperature shows that the dissolving power depends upon chemical and not upon physical factors, since, by heating, the osmotic tension of the serum is not changed.

The blood of cold-blooded animals does not respond to the test so readily as the blood of mammals, the nucleated corpuscles evidently possessing greater resistance. Non-defibrinated mammalian blood requires longer for the dissolving of its

corpuscles than if the fibrin be removed. Control experiments with superheated serum show that the dissolving, which does at length occur, is not due to the action of bacteria developed in the serum. On the contrary, the dissolving power of the serum is inhibited by the increase of bacteria.

Thus far the dissolving action of serum has been demonstrated only among vertebrates. So far as tried, the blood of invertebrates (Cancer, Arenicola, sea-urchin) has no globulicidal effect upon the erythrocytes of vertebrates (gull, rat). Among cold-blooded vertebrates the action is so slow as to be best observed under the microscope. Only the serum of Anguilla acted so rapidly as to make macroscopic observation easy. It was noted that sera which are particularly poisonous, such as the serum of Anguilla, the domestic fowl, and cat, act most rapidly upon corpuscles. This suggests that both effects are due to chemical substances of the same class.

The serum of Anguilla dissolves the corpuscles of mammals, birds, reptiles, and amphibians, and also that of other fishes. The blood of *Acanthias vulgaris* is quickly dissolved by Anguilla serum, and so is the blood of other teleosts, as *Labrus maculatus*. The effect of Anguilla serum upon the blood of other Murænidæ was not tried. The serum of Acanthias dissolves the erythrocytes of the gull, mouse, and of teleosts (Labrus, Anguilla). It is not entirely indifferent toward the blood of other elasmobranchs (*Raja batis*).

Among Amphibia, Anura are easily distinguished from Urodela by difference in blood. Frog corpuscles are dissolved by the serum of Anguilla, the gull, and cat. The dissolving power of amphibian blood is less in animals that have been kept in captivity for some time and poorly fed.

Among reptiles, the serum of some snakes was found to exceed that of amphibians in globulicidal action. Yet more powerful is the action of bird serum. This fact is parallel to the fact that the serum of birds is especially poisonous to other vertebrates. This common quality of the serum of reptiles and birds is correlated with similarities in anatomical structure which have caused reptiles and birds to be classed together as Sauropsida. The serum of the domestic fowl

dissolves the erythrocytes of animals from all other classes of vertebrates, and also of other birds.

The results of the experiments with sera of mammals agree entirely with the results of Landois's experiments with transfusions, but they do not agree with the results obtained by Ehrlich and Morgenroth, Bordet, and Gürber. This lack of agreement is doubtless due to difference in methods. The investigators named above washed out by isotonic salt solution all the serum from the erythrocytes of one animal and added large quantities of the erythrocytes to the serum of another animal. By this method in many cases no globulicidal action can be observed, while, if a small quantity of simply defibrinated blood be added to the serum, the erythrocytes are quickly dissolved. The importance of adding only small quantities of blood to the serum lies in the fact, observed by Buchner, that in the mingling of two different sera the globulicidal action may be either increased or diminished. In transfusion experiments the more blood injected the better.

The carotid arteries of a cat and an ocelot were connected so that an exchange of blood took place from one animal to the other. After a short time the blood of each animal was supposably well mingled with that of the other. No hemoglobin appeared in the bladder of either animal. The blood of the cat and of the ocelot is physiologically equivalent. If a cat and a rabbit be connected in the same way, both animals die in a few minutes from the poisonous effects of the foreign blood upon the central nervous system. Death occurs before any globulicidal action takes place. Two rabbits connected in this way exhibit no pathological symptoms.

The experiments upon mammals lead to the conclusion that among animals of the same family there are no marked differences in blood ; but the blood of animals of different suborders is not physiologically equivalent, while the blood of animals of different orders exhibits very marked mutual globulicidal action. The blood of the mouse and blood of the rat are mutually inactive. The blood of the hare and of the rabbit is equivalent; but rabbit serum dissolves corpuscles of the guinea-pig, and rabbit corpuscles are dissolved by serum of the guinea-pig,

these animals belonging to different families. The blood of the rabbit is equivalent only to that of the hare, of all the animals experimented upon.

Of Perissodactyls, serum of either the horse or ass is inactive toward corpuscles of the other, but horse serum dissolves corpuscles of the rabbit, guinea-pig, calf, lamb, and man.

Of Artiodactyls, the serum of either the ox or swine dissolves corpuscles of the other, and both dissolve corpuscles of the dog, cat, horse, rabbit, and man.

Of Carnivora, the blood of the dog, fox, and wolf is equivalent, but serum of either the dog or cat dissolves corpuscles of the other. The serum of either the cat, ocelot, or jaguar is inactive toward corpuscles of the other two animals, but cat serum dissolved the corpuscles of all the other mammals tried.

Finally, among primates, human serum dissolves the corpuscles of fishes, frog, snakes, pigeon, fowl, night-heron, horse, swine, ox, rabbit, guinea-pig, dog, cat, hedgehog, and lemur. The effect of human serum was tried upon the blood of six species of apes (the platyrhines, *Pithesciurus sciureus*, *Ateles ater;* the catarrhines, *Cynocephalus babuin*, *Macacus sinicus*, *Macacus cynomolgus*, and *Rhesus nemestrinus*, at the Berlin Zoölogical Garden). In all cases the human serum dissolved the ape corpuscles. The serum of Macacus had no effect upon the blood of some persons, while the blood of others was quickly dissolved by it.

Among the true anthropoid apes is first found blood which is physiologically equivalent to that of man. To 5 c.cm. of transparent human serum was added a drop of blood from the finger-tip of an orang-outang, and in another case from a gibbon, both young animals from the Berlin Zoölogical Garden. After twelve hours the red corpuscles were separated from the serum by the centrifuge, apparently having suffered no change, while the serum remained free from color. In three experiments, where 10 to 20 c.cm. of fresh, defibrinated human blood was injected into the veins of *Macacus cynomolgus* or *Macacus sinicus*, only a small quantity of hemoglobin appeared in the urine, — scarcely more than is found in the serum as a

result of the defibrinating process. The animals suffered no ill effects from the operation. Twenty-five cubic centimeters of human blood was injected into a ten-year-old chimpanzee. For two days the urine was tested and showed no signs of hemoglobin or albumen. The injected blood apparently produced no effects whatever. It has been shown by successful blood transfusion experiments that the blood of such widely separated races as the negro and white is physiologically equivalent.

These blood comparisons, as well as the embryological researches of Selenka, justify placing man and the anthropoid apes together in the same family, or at least in the same suborder, rather than isolating man in a suborder of primates, coördinate with the suborders of the platyrhines and catarrhines.

The chemical similarity of the blood of morphologically similar animals is not surprising. The thing inherited through the ovum and spermatozoön is not "innere Impulse," "Iden," or "Entwickelungsmöglichkeiten," but a certain definite chemical composition of the molecule. Development, form, and the nature of the metabolic processes are as closely dependent upon the chemical composition of the molecule as any chemical reaction is dependent upon the chemical composition of the reagent causing it. Similarity in the chemical composition of blood is but one factor in the chemical similarity of closely related organisms. The chemical similarity of reproductive cells must be regarded as an epitome of all the chemical similarities of the adults.

It is well known that the horse and ass, dog and wolf, rabbit and hare readily cross. It would be a valuable experiment to attempt, by means of artificial fertilization, a cross between the rat and mouse, or between the domestic cat and the ocelot. The physiological similarity of the blood of either pair of animals points toward the possibility of a successful crossing.